INVENTING TO LEARN

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ABSTRACT

A method of instruction is presented in which learners construct their own understanding by engaging in experiments directed to solving specified problems. The method is based on how successful inventors learn and create new inventions.

INTRODUCTION

Whoops of triumph erupt from the distant corner of the classroom as a team of inventors has just broken the class record. Their model car rolled down a ramp and across the floor for a distance of 28', farthest for the day. Their enthusiastic high-fives spur them to try even more improvements to their car. This class is learning science, technology and teamwork. They are learning by solving problems in hands-on and real world projects. What propels them to work diligently is the freedom they have to succeed, fail, and learn in their own way.

All the similarities between the student inventors and professional inventors are intentional. Inventors learn by proposing solutions to problems, building mock-ups, testing and improving them, and then communicating their successes. This is authentic learning- learning that applies to the real world and it's the learning that occurs for each inventor in his or her own preferred learning style. It's the learning that comes from the personal and team enquiry into a problem; and it's the learning that appeals to every child and adult.

Edison, Glenn Curtiss, Charles Kettering and many of the other great inventors didn't do well in school. To achieve their inventing success they learned at their own speeds and in their own ways, using their hands as well as their minds, tackling real world problems. Many bright kids today, like the great inventors, would learn much better in an environment where they can learn actively.

"Inventing to Learn"

Inventing to Learn has been used in a variety of learning environments over the last decade. Initially it was tried in informal learning settings: *Camp Invention* (at the National Inventors Hall of Fame) and more recently at *Kids Invent Toys* (started at California State University, Fresno; www.kidsinvent.com). Hundreds of thousands of kids have now experienced inventing to learn in these summer and holiday programs. Now the methodology has been extended to teach robotics and to teach standards-based science in classrooms (*Inventing Toys:*

Student in Kids Invent Toys summer camp at California State University, Fresno

Kids Having Fun Learning Science, Loco-motion: Physics Models for the Classroom, and *Rocket-Powered Science).*

From elementary schools to graduate schools "inventing to learn" generates the same positive response. Students have fun, work hard, and learn. The method is robust across grade and age levels, and is equally applicable for both genders.

The benefits of inventing to learn are manifold. Learners are actively involved throughout the experience. From the moment they enter the classroom or laboratory, they are engaged in solving problems. Since learning doesn't occur unless the learner starts thinking, challenging students to solve problems gets them into thinking and learning. Since they are active, they are alert, having fun and rarely causing problems.

Their interest doesn't wane as the activity proceeds. Inventing requires teams to make devices, test them, and improve them. The first model might not be good enough. Unlike most school experiences, inventing to learn teaches constant innovation. The natural competitive spirit keeps them improving their inventions.

The sense of competition doesn't stifle interest; it accelerates it. Some teams take pride in meeting the specific challenges, while others take pride in the unique designs and even the grand disasters their teams made.

The learning occurs in making things work. Kids are used to work in two dimensions: designing, drawing and writing. The challenge is, transforming designs and mental models into three-dimensional devices that work. That's where the universal laws of physics and engineering provide the reality test of ideas. When Edison said that inventing was one percent inspiration and 99 percent perspiration, he was referring to this phase. Dreaming up ideas is easy, making them work is difficult.

Students test their models of balloon-powered boats.

Because students work in teams, there is a great sharing of information. Teams share information and experiences to make their projects succeed. With experience, teams develop comfort sharing information with other teams. Most learning in inventing activities occurs from team experiences (experimenting) and from sharing information with teams (communicating successes and failures). Not having to be the perpetual fountain of knowledge, frees the teacher to focus on helping kids who really need help and helping the brightest kids go farther.

Inventing engages people because it meets Csikszentmihalyi's criteria (*Flow)* for autotelic experiences. Autotelic experiences are those that people engage in, because they are inherently enjoyable. Golfers, bowlers, artists and everyone else who engages in a hobby or sport does so because the activity is autotelic. "Inventing to learn" changes learning from a passive and low efficiency experience into an autotelic experience - lively, fun, and filled with learning.

To make learning fun, the experience is transformed from a delivery of words into establishing challenges. The challenges presented are doable, but success is not guaranteed. The problems do not come with a cookbook solution and few or no clues are provided. At the outset, teams don't know how to solve the problem, but think that they are capable of solving it. Almost always, they do solve it. If they aren't able to come up with their own workable solution, they borrow ideas (learn) from other teams.

Once teams start on a challenge, they really focus on it. Interruptions and interferences with their designs, are minimized even when it is apparent they are headed for failure. Spectacular failures are celebrated and provide optimal opportunities for learning. Often they better illustrate the underlying science than do successes.

One of the most important requirements for autotelic learning is that the students should have a clear understanding of the challenge. The challenges are specified as open-ended and measurable. Eg "Build a car that can travel as far as possible under these conditions." Once they see the experimental set up, they understand what they need to do. They don't run to the teacher to ask if they're doing the project correctly. They see how they're doing each time they test their models. This immediate feedback, coupled with the self-determination of each team, provides a powerful stimulus for teams to work hard.

Measurable goals add the experience of measuring and recording data as well as giving students immediate feedback on their progress. Students collect real data and, in many activities, graph it. Before going onto the next phase of the project they present their graph and interpret it to the teacher.

Challenges can be created to meet nearly all of the physical science content standards and technology standards, plus all of the science method standards in national and state requirements. In essence, each inventing challenge is a self-directed (or team directed) inquiry. Teams generate hypothesis (solutions), test them (experiment), record data and later report on their project. For informal learning, web pages are used as the preferred method of reporting.

"Inventing to Learn" in the class room

Here's how an "inventing to learn" activity goes. We issue a challenge. "Working in teams of your own choosing, can you make a car that rolls down this ramp and across the floor? We want to find the design that rolls farthest." Self-selected teams usually work well, but we limit them to not more than three people per team.

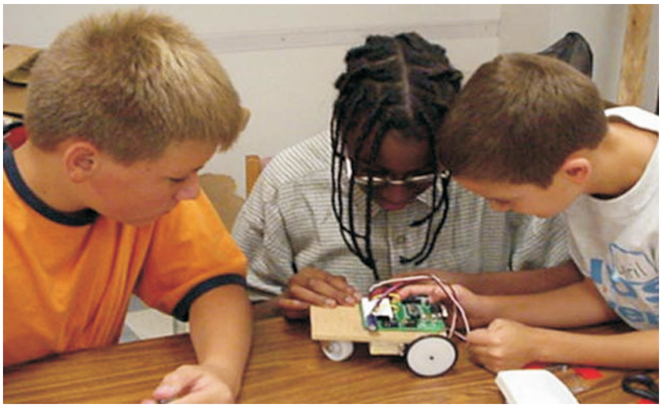
We show them the materials available. With younger children we often show them a model. Showing a model reduces the frustration, but also limits the creativity: most of the solutions look similar to the model we show. After showing the materials we provide little information. When asked, if teams should do this or do that, we answer, "Yes." We are more interested in the learning process than in teams making great toys.

Testing water rockets

Inventing is a fast-paced activity and we emphasize that time is limited. Teams that dawdle run out of time. We encourage teams to "Make mistakes as quickly as you can." By that we mean to build and test quickly, rather than spending more time trying to figure out what works on a 2-dimensional design. Teams that make mistakes quickly, succeed. Mistakes teach and each one is, as Edison said, a stepping-stone to eventual success.

We station ourselves at the test station, because that's where most of the learning occurs. Typically kids aren't able to report what happened during a test. When asked, "What did your car do?" answers range from "I didn't see it" to "I'm not good at this." We don't let them off the hook with these responses. We have them test it again, knowing that we're going to ask again. The first requirement in any science experiment is, to be able to report accurately what happened, and kids learn this during inventing.

When we agree on what happened to their cars, we ask them why that happened. Again, most students are unable to suggest what occurred. They respond to the



A team of students troubleshoots a problem with the robot they built.

question with a barrage of buzz words from their science memory: "potential energy," "friction," or "acceleration." Rather than thinking, they blurt out the first bit of vocabulary they remember.

We insist them to look at their model and point to something on the model that might have caused the observed behavior. If reporting is the first requirement of science, associating causes with effects is the second. Sadly, most kids aren't used to doing this.

Kids measure the distances their cars travel and record that on the board for all to see. We announce new records, both as a reward to the team that set the record and as an incentive for other teams to work hard. We also show off creative designs, regardless of their success. When we show successes and failures, we focus on the design and not the team. We ask questions about which features lead to success or failure and what the underlying science is.

Schools program the kids to do a project once and quit. The real world is different and in inventing we emphasize incremental improvements in models. We encourage teams to extend their success. Good is okay, but let's try for great.

As teams test their cars (or other projects) we look for opportunities to confront their native misunderstandings and to introduce the concepts and vocabulary of science and technology. Once the projects start, most of our time is spent on individual (and small team) instruction. Teams work well on their own, which let the teacher to focus on the learning in the teachable moments.

Behavior problems disappear in "inventing to learn." Students are fully occupied designing and building their own models and in measuring their success, so they have no time, energy, or desire to engage in anything other than the activity.

Culmination occurs in class discussions or in team project reports. With inventing, reports can be extended to include paper research to tie in famous inventors or inventions. Projects and poster board reports make great displays on "parents' nights".

Conclusion

In designing projects to use with this method, we strive to find projects that require common and inexpensive materials and projects that allow easy measurement of results. Most common measurements are dealing with distance, since meter or yardsticks are among the few measurement devices found in most classrooms.

We use the same projects for elementary school kids and graduate students in physics. Everyone learns something, learns at his or her own level and own speed.

"Inventing to learn" is a powerful technique that has broad applications. We believe that other creativity-based learning techniques are equally powerful. For example, creative writing and art could be applied in the same pedagogic model to focus on language skills, history, and other studies.

We have given teacher workshops and programs for students throughout the US and Canada, and in Sweden, Malaysia, Singapore, Holland, and Scotland. Teachers and kids everywhere like this approach.

Adopting the "inventing to learn" method changes the way teachers teach. It allows them to focus on individualized learning while the class is engaged in learning work, set in real world situations. Students love the methods of directing them to perform their own work and learn much more than they would in a traditional classroom. An "inventing to learn" classroom resembles the work places of the 21st century where workers create new knowledge. As such, this method is an ideal way to teach.

References

Csikszentmihalyi, Mihaly. Flow 1990. Harper & Row.

Sobey, Ed. *Inventing Toys Kids Having Fun Learning Science*. 2001. Zephyr.

Sobey, Ed. *Loco-motion, Physics Models for the Classroom.* 2005. IPG.

Sobey, Ed. *Rocket-powered Science.* 2005. GoodYear Books.

ABOUT THE AUTHOR

Ed Sobey is science educator, author, and former museum director. He has directed five museums including the US national museum of inventing, the National Inventors Hall of Fame. While directing A.C. Gilbert's Discovery Village, Ed founded the US National Toy Hall of Fame, now at the Strong Museum in New York. Ed holds adjunct faculty positions at Seattle Pacific University and California State University, Fresno, where he developed Kids Invent Toys, a technology-learning program used now by universities and museums in North America and Asia. He is the Senior Partner and Director of the Asian Institute of Creativity, Innovation, and Entrepreneurship based in Singapore and President of the Northwest Invention Center in Redmond, Washington. He has published 16 books, including The Field Guide to Roadside Technology. Ed hosted an award-winning science program ("Blow the Roof Off") for the Ohio public television system and developed and hosted an inventing-based television show, "The Idea Factory," for KFSN-ABC in California. He holds a Ph.D. in oceanography and is listed in Who's Who in America. Ed is a Fellow in the Explorers Club, having led and participated in expeditions to Antarctica, a crossing of the Pacific Ocean by sailboat, El Nino studies off South America, and ocean kayak expeditions to Alaska.